Effect of low-temperature for the treatment of municipal wastewater in a full-scale BAF

HAN Hongjun, HU Hongbo, XU Chunyan, LI Yufei
State Key Laboratory of Urban Water Resources and Environment, Harbin Institute of Technology
Harbin, China

Abstract—The impact of temperature on nitrification in biological aerated filter (BAF), process was studied in order to improve the nitrification performance in municipal wastewater treatment. When the water temperature dropped, the nitrification performance obviously deteriorated. Effects of important process variables such as DO concentration and backwash period to nitrification performance were investigated when the water temperature dropped from 23°C to 9°C. The study shown that by raising the DO concentration to enhance nitrification performance was not available in low water temperature environment and by extending the backwash period to enhance nitrification was available. The effluent NH4-N concentration reduced from 8mg/L to 6.5mg/L, when the backwash period extended from 48 hours to 65 hours and the the effluent concentration of SS and head loss were all in a permissible range.

Keywords: BAF; Nitrification; Temperature; DO; Backwash period

I. INTRODUCTION

The biological aerated filter (BAF) process is developed in Europe and then widely applied all over the world as a novel wastewater treatment system due to its advantages relative to other systems [1]. The most important advantage of this process is its compactness for construction, caused by the high volumetric removal rate and the simultaneous solid-liquid separation and biological reaction in the same reactor [2,3]. Because of its superior own conditions, BAF has become the preferred treatment of many kinds of wastewater all over the world [4]. In a single unit operation of BAF, carbonaceous BOD removal, solids filtration and nitrification can be achieved [5]. In a recent development, BAF systems have been selected for many small or large towns for wastewater treatment or reuse purpose throughout the world[6].

Nitrification is an aerobic, autotrophic process used for conversion of ammonium to nitrate which entails two steps. Ammonium is converted to nitrite by Nitrosomonas species in the first step and nitrite is converted to nitrate by Nitrobacter species in the second[7]. One of the major factors affecting nitrification in water treatment is temperature[8,9]. Low temperatures have generally a drastic effect on bacterial process rates, a phenomenon characteristic of all biochemical systems[10]. The objective of this study was to evaluate the impact of temperature and find the method to settle in BAF used for nitrification in the treatment of municipal wastewater in cold conditions. Experiments were carried out in Dalian (China),on a full-scale project.

II. FULL SCALE PROJECTS MATERIALS AND METHODS

A. Malanhe Wastewater Treatment Plant(second stage), Liaoning, China

Malanhe WWTP is a municipal wastewater treatment plant in China, with an average capacity 80000m³/d. The effluent need to meet the demands of “The Integrated Wastewater Discharge Standard (GB18918-2002)Level-one A”. The raw wastewater average water quality and the effluent standard is shown in table 1. In order to avoid the large additional carbon source cost for denitrification, a pre-denitrification biological aerated filter system was selected among other chemical, physical and biological treatment processes evaluated.

Raw wastewater flowed through three coarse screens and is then pumped to the pre-treatment, which consists of three rotating drum grizzly screen and two aerated grit and six hydrolysis-precipitate tank. Ferric Chloride was added to the hydrolysis-precipitate tanks for phosphorus removal. The effluent gravitated from the hydrolysis-precipitate tank into a distributing channel, to be assigned to seven denitrification filter (DN filter). Then the effluent gravitated from the DN filters into two distributing channels, to be assigned to fourteen carbon and nitrogen removal filter (CN filter), which is the heart of the treatment and the center we researched. For final disposal, the wastewater was conveyed to a discharge tank, from where it was pumped through a pipeline to the Bohai Sea after disinfection by ultraviolet light. The water which was used for backwash was derived from the discharge tank, and the backwash sludge liquor from the filter was returned to the influent. A plant flow scheme is shown in Figure 1.

Fig.1 Flow scheme of treatment process

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### Tab.1 Influent Quality

<table>
<thead>
<tr>
<th>Parameter (mg/L)</th>
<th>Average Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended solid</td>
<td>150 ~ 200</td>
</tr>
<tr>
<td>Chemical oxygen demand</td>
<td>150 ~ 400</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>10 ~ 45</td>
</tr>
<tr>
<td>NH₄-N</td>
<td>25 ~ 40</td>
</tr>
<tr>
<td>PO₄-P</td>
<td>2 ~ 5</td>
</tr>
</tbody>
</table>

### B. The CN biological aerated filter

The nitrogen removal filter (CN filter) is a typical upflow biological aerated filter (BAF), which is used for nitrification and organic pollutants removal. There are 14 CN filter in this system and each filter consisted of 0.3m of pebble bed overlaid by 3m of ceramsite medium for a total depth of 3.3m. Because a pre-denitrification process is adopted, DN filter consumed a majority of carbon in wastewater, so the primary use of CN filter is nitrification. One of the major factors affecting nitrification in water treatment is temperature. The temperatures range from 10 to 20°C in Dalian and a strong temperature impact on BAF for the removal of ammonia is shown when the temperature is below 15°C.

### III. RESULTS AND DISCUSSION

#### A. Effect of temperature on nitrification

The effect of water temperature on performance of nitrification project was investigated in long time (2008.9 ~ 2009.1) after the system has been stable operation. During this period the highest temperature reached 23°C, the lowest reach 8°C.

Figure 2 depicts effect of raw water temperature on the NH₄-N removal efficiency. The effluent NH₄-N concentration in different temperature

So, some methods were needed to improve the nitrification efficiency in low-temperature environment.

#### B. Effect of DO on nitrification at different temperature

As we all know, DO concentration is an important influence factor in nitrification. Increasing DO concentration contributes to raise the efficiency of nitrification. As shown in Figure 3 and Figure 4, they show nitrification performance at different water temperature. Figure 3 depicts effect of DO concentration on the NH₄-N removal efficiency during commissioning in September 10 to September 20 when the water temperature was about 23°C to find out a feat DO concentration in CN filter. Figure 4 depicts effect of DO concentration on the NH₄-N removal efficiency in January 5 to January 15 next year when the water temperature was about 9°C to find out whether it was effectually to increasing DO concentration in low-temperature environment.
in NH$_4$-N removal efficiency from 81% to 86%. So a 5.5 mg/L DO concentration was adopted in this project finally.

Figure 4 depicts the effluent concentration and removal efficiency of NH$_4$-N at various DO concentrations at low water temperature. Before this, effluent DO concentration was controlled at 5.5 mg/L. As shown in Figure 4, by increasing the frequency of roots blower the DO concentration was raised from 5.5 mg/L to 9 mg/L. Effluent NH$_4$-N concentration exhibited a negligible decreasing trend as the DO concentration gradually increased. When the DO concentration increased from 5.5 mg/L to 9 mg/L, the effluent NH$_4$-N concentration decreased only about 0.5 mg/L. Thus it can be seen: by raising the DO concentration to enhance nitrification performance is not available in low water temperature environment.

C. Effect of backwash on nitrification at different temperature

The CN filters need a backwash per 48 hours to release the accumulated solids and remove the excess biomass. From the filter completing backwash to next backwash beginning make up a backwash period. In the period the nitrification performance of CN filter is different in both high temperature and low temperature.

Figure 5 depicts the effluent concentration of NH$_4$-N at various times in the whole backwash period. One curve is made in September 10 to September 20, 2008 when the water temperature is about 23°C, another is made in January 5 to January 15, 2009 when the water temperature is about 9°C. Due to the raw wastewater concentration of NH$_4$-N fluctuated in the period, distinct CN filters were detected in same time. (These filters were in different time of the backwash period and other factors were all same, so we can think dates test from these filters are same as dates test from one filter in different backwash period time.)

As shown in Figure 5, effluent NH$_4$-N concentration exhibited a decreasing trend in backwash period, in other words, the nitrification performance get better and better both in high temperature and low temperature. The reason may be that the biofilm became thicker and the biomass become larger as time goes on. Carbon and NH$_4$-N removal was carried out by the microorganisms that grew attached to the filter packed media. As the biomass growth produced an increase in biofilm thickness and a decrease in bed porosity, the head loss over the filter bed was increased, necessitating backwashing.

But in this project it is not reached the maximum level when using a 48-hour backwash period. So the method that extension the backwash period is adopted to raise nitrification performance. There are two shortcomings or called limiting factor for extension the backwash period. One is effluent SS concentration another is head loss. Effluent SS concentration and head loss both exhibited an increased trend as time goes on. And the allowable maximum head loss is 1.5 m when CN filter reached maximum levels, the allowable maximum effluent SS concentration is 10 mg/L to meet the demand of effluent standard.

Figure 6 shows the head loss at various time in a extended backwash period with a ordinary filtering velocity in about 4.96 m/h and a force filtering velocity (One of a filter is stopped influent water because of being backwash ) in about 5.34 m/h. As shown in this figure, the head loss reached a maximum value in 75 hours in the force filtering velocity. So the backwash period should not be exceeded 75 hours for security purposes.

Figure 7 shows the effluent concentration of NH$_4$-N and SS at various times in an extended backwash period for about nearly 75 hours. At this moment the maximum head loss is nearly 1.5 m, the filter has reached the limit, the period can not be extended anymore. The effluent NH$_4$-N concentration increased and effluent SS concentration decreased as time goes on. The effluent SS concentration reached 10 mg/L in 65 hours time and the effluent NH$_4$-N concentration settled to 6.5 mg/L this moment, lower nearly 1.5 mg/L than 48 hours time. So a
65 hours period was adopted in low-temperature period after January 2009.

Figure 8 presents the effluent concentration of NH₄-N, SS and head loss when a force filtering velocity was used since the new backwash period were adopted from January 6 to January 18 under a water temperature in about 9°C.

![Graph showing effluent concentration and head loss over time](image)

**Fig. 8** The NH₄-N, SS concentration and head loss in a longer time

Figure 8 shows a steady value in each effluent item in a longer time. The effluent NH₄-N concentration settle to 6.5mg/L, the effluent concentration of SS settle to 10 mg/L and head loss settle to 0.9m. Namely that effluent NH₄-N concentration reduced to 6.5mg/L in low water temperature in about 9°C through extending the backwash period from 48 hours to 65 hours.

**IV. CONCLUSION**

Biological nitrification of municipal wastewater was studied in a full-scale BAF projects in low-temperature water environment. Effects of important process variables such as DO concentration and backwash period to nitrification performance were investigated when the water temperature dropped from 23°C to 9°C.

Effluent NH₄-N concentration exhibited a decreasing trend as the DO concentration gradually increased. The DO concentration increased from 3 mg/L to 5.5 mg/L, the effluent NH₄-N concentration decreased from 7.5 mg/L to 4.3 mg/L, as soon as the DO concentration continue to increase, the effluent NH₄-N removal efficiency increased slowly, the DO increased from 5.5 mg/L to 9 mg/L, the effluent NH₄-N concentration decreased from 4.3 mg/L to 2.8 mg/L in September when the water temperature is about 23°C. So a 5.5 mg/L DO concentration is adopt in this project finally. When in January next year the water temperature dropped to 8°C, the effluent NH₄-N concentration increased to 7-8mg/L. The DO concentration was increased from 5.5 mg/L to 9 mg/L but the effluent NH₄-N concentration only decreased about 0.5 mg/L. Thus it can be seen: by raising the DO concentration to enhance nitrification performance is not available in low water temperature environment.

The backwash period of CN filters is 48 hours as a general rule. In the period the nitrification performance of CN filter get better and better as time goes on in both high temperature and low temperature environment. The effluent NH₄-N concentration reduced from 8mg/L to 6.5mg/L, when the backwash period extended from 48 hours to 65 hours and the effluent concentration of SS and head loss were all in a permissible range.

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**REFERENCES**


